Tropical Cyclone tracks in present and future climates

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Due to the large social and economic impacts of tropical cyclones, it is fundamental to understand possible changes in tropical cyclone activity due to climate change. In this project we will focus on how tropical cyclone tracks could be influenced by climate change, especially due to the most robust projected changes in the tropical circulation. Tropical cyclone tracks strongly influence many tropical cyclone properties - including intensity and landfall frequency and location - which are of great importance to local populations. We will study changes in tropical cyclone tracks due to both natural variability and anthropogenically forced trends. As part of our analysis we will apply a cluster technique that we have previously applied to observed tropical cyclone tracks in different regions of the world, and that has given important insights on the different properties of tracks in different cluster types: e.g. seasonality, genesis location, intensity, landfalling rates and locations.

Our first approach will be to examine tracks of tropical cyclones in global and regional climate models under present and future climate scenarios. We will apply the same cluster technique to identify tropical cyclone track changes in future climate scenarios and the large-scale circulation associated with those changes. The analysis will be performed using output from many models, to assess the robustness of these track changes as well as the relevant dynamics.

The second approach is to examine synthetic tropical cyclone tracks generated by a statistical-dynamical as well as a purely statistical approach. These tracks will be associated with current and future climate scenarios. We will then compare the cluster analysis of synthetic tracks to that of the dynamical models' tracks. By using two distinct approaches, we will be able to make a detailed assessment of the robustness of the possible track changes in future climate. The long-term objective of this project is to build a scientific foundation for future projections of tropical cyclone landfall change associated with climate change.

Understanding and predicting tropical and North Atlantic SST forcing on variations in warm season precipitation over North America

University of Nebraska-Lincoln (PI: Dr. Qi S. Hu, Co-Is: Dr. Robert Oglesby and Dr. S. Feng)

Abstract

The overall objective is to use diagnostic and modeling methods to decipher and understand physical processes/causal links that connect tropical and North Atlantic sea surface temperature (SST) variations associated with the Atlantic Multidecadal Oscillation (AMO) to changes in atmospheric circulation and warm season precipitation regimes for North America. The ultimate goal is to include representations of these processes in forecast models, and thereby improve predictions of summer rainfall variations at intraseasonal, interannual, and decadal timescales for North America, particularly the monsoon region and the central U.S.

Scientific questions that will be addressed are: How do the heat and momentum flux anomalies arising from AMO forcing act to develop anomalous regional circulation and rainfall in North America during different phases of AMO? Are atmospheric eddy heat and momentum fluxes and circulation anomalies during different phases of AMO sufficient to account for observed summer rainfall regime changes in North America, and if so, how? How have Pacific Decadal Oscillation (PDO) and ENSO interacted with AMO effects on circulation/rainfall regimes for North America? How have spring soil moisture anomalies interacted with the specific warm season eddy heat and momentum flux anomalies for North America during different phases of AMO to modulate rainfall development and variation? How can the AMO forcing be included in forecasting models and improve summer rainfall predictions?

Methods used include the Eliassen-Palm diagnostics, which will be used to quantify eddy heat, momentum, and energy fluxes driven by SST anomalies related to AMO and effects of these eddy fluxes on circulation and summer rainfall regimes for North American during different phases of AMO. Both general circulation model (GCM) and regional climate model will be used to determine AMO forcing and its modification by PDO and ENSO. Specifically, the atmospheric GCM will be integrated with observed SST forcing in the central and North Atlantic Ocean, and climatological SST elsewhere. Additional GCM runs with SST forcing from the Pacific Ocean will be made in order to identify their effects on the AMO induced circulation and rainfall patterns in North America. Regional model will be integrated with initial condition and lateral forcing from observations and GCM output in order to examine in detail changes in moisture and energy transports, precipitation development, and their intraseasonal and interannual variations during the different circulation regimes associated with AMO. Regional model also will be used to examine feedbacks of land surface processes (e.g., soil moisture) to the circulation anomalies and rainfall development during different phases of AMO.

The expected key outcome is improved understanding of how summer rainfall variations on intraseasonal and interannual timescales are associated with the forcing from AMO and how these variations have changed during different phases of AMO (thus explaining also decadal timescale variations in summer rainfall in North America). This understanding will be communicated to forecasting modeling groups, with the ultimate goal of improving predictions of intraseasonal and interannual rainfall variations (including likelihood of floods) for North America.

Understanding atmosphere-ocean coupled processes in the southeast Pacific

Principal Investigators:

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Abstract

Coupled atmosphere-ocean general circulation models (CGCMs) have systematic errors in the southeast Pacific (SEP) region. The biases need to be traced back to specific model characteristics, such as certain aspect of the physical parameterizations, in order to provide useful guidance on how to improve the model simulation. The primary goal of this proposed study is to improve our understanding of the structure and mechanisms of CGCMs' systematic biases in the southeast Pacific. To realize this goal, we need to examine, step by step, the key biases in its AGCM, the key biases in its OGCM, and the key biases in its ocean-atmosphere feedback processes when the AGCM and OGCM are coupled together. Therefore, we propose to:

(1) Diagnose the structure and mechanisms of the AGCM biases in stratocumulus/stratus clouds, marine boundary layer (MBL), and surface fluxes in the SEP region in IPCC AR5 CGCMs;

(2) Analyze the upper ocean currents, thermal structures and heat budget in the SEP region in IPCC AR5 CGCMs;

(3) Examine the ocean-atmosphere coupling processes in the SEP region in IPCC AR5 CGCMs, especially how well the ocean-atmosphere feedbacks are simulated; and

(4) Conduct forced OGCM experiments to examine the sensitivity of upper ocean processes to atmospheric forcings relevant to AGCMs' biases.

Evaluation of the Tropical Storm Track Across the Intra-Americas Sea in IPCC AR5 Models and the Mechanisms of Change in a Warmer Climate

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Abstract

The Intra-Americas Sea (IAS) includes the Gulf of Mexico, Caribbean Sea and tropical northeast Pacific Ocean, the latter of which is the most prolific hurricane formation region in the world per square meter. Heavy rains arrive over the IAS during boreal summer, when the Inter-Tropical Convergence Zone (ITCZ), or axis of the tropical storm track, migrates north off the equator and SSTs warm throughout the region. Localized moisture convergence over land areas within the IAS is important for hydropower, agriculture and fresh water supplies. IAS moisture transport into northern Mexico and Southwest U.S. is also important for agriculture and populations in these regions.

Several studies point out the critical role that orography plays in present day mid-latitude and tropical storm tracks. Recent work also suggests that the Caribbean low-level jet (CLLJ) influences storm track activity within the IAS. Studies of tropical storm tracks within the projected warmer conditions of the 21st century find reduced storm track activity in the tropical Atlantic and a shift of the tropical northeast Pacific storm track southward. The intensity of tropical storms overall appears to remain unchanged in studies that have accounted for a mean shift in the tropical mean sea surface pressure due to warmer temperatures. However, predicting storm intensity changes remains a difficult task, as this parameter is more dependent on model resolution than storm frequency.

The following questions are raised by these studies: i) Will the roles of orography and the CLLJ change if the storm track in the tropical eastern Pacific shifts southward in the 21st century? ii) How would such a change affect intensity of storms in the tropical eastern Pacific? iii) How would changes in the position of the tropical eastern Pacific storm track affect the precipitation over land areas of the IAS and NAM regions?

This study proposes to investigate these questions through the following set of analyses:

- Obtain 20th century tropical storm track statistics using state-of-the-art reanalyses.
- Assess tropical storm track statistics of all AR5 model 20th century scenario data available at greater than daily resolution against the reanalyses' statistics.
- Use high-resolution regional model simulations to assess physical mechanisms associated with several real cases of developing and non-developing tropical depressions within the IAS using the reanalyses as boundary forcing for these simulations.
- Force the regional model for actual cases of 21st century storms/waves from AR5 models that produce realistic track statistics for the 20th century and compare mechanisms of storm initiation and intensification with the cases from step 3.

This project will make use of a numerical technique in which actual features of the tropical storm track (easterly waves and mature storms) in the AR5 models will be simulated using a high-resolution regional model, rather than using idealized simulations of a mature tropical storm forced with the general conditions of a warmer climate. This approach permits changes in genesis mechanisms to be evaluated.

B. Abstract

Project Title:	"Remote versus local forcing of intraseasonal variability in the IAS region: Consequences for prediction."
Principal Investigators:	Eric D. Maloney, Colorado State University/CIRA (Lead PI)
	Shang-Ping Xie, University of Hawaii/IPRC

Strong intraseasonal variability in hurricanes and other extreme events occurs over the Intra-Americas Sea (IAS) region during boreal summer. Observations and global and regional climate models indicate significant 50 day spectral peaks in precipitation, winds, SST, and synoptic-scale wave activity in the IAS region. While the global Madden-Julian oscillation (MJO) is likely a significant influence, the extent to which intraseasonal variability in the IAS region can be generated in isolation from remote influences is an open question. Of interest for prediction, evidence exists that strong MJO precipitation variability in the west Pacific can generate atmospheric Kelvin wave fronts that propagate eastward into the IAS region and initiate intraseasonal events. It is notable that the genesis of Hurricane Katrina coincided with propagation of a cold intraseasonal Kelvin wave from the west Pacific into Americas. If intraseasonal variability in the IAS region is primarily remotely forced, significant forecast lead time may exist for the onset of strong intraseasonal events in the IAS region. The following questions will be addressed in an observational and multi-model approach:

1. Is intraseasonal variability in the IAS region primarily locally or remotely initiated? We will use regional and global models to assess the remote versus local control of intraseasonal variability in the IAS region. Lateral boundary conditions in the IPRC regional ocean-atmosphere model (IROAM) will be modified to either admit or suppress intraseasonal dynamical signals entering the IAS domain from the west Pacific. Experiments will also be designed to suppress remote intraseasonal influences on the IAS region in a global general circulation model (NCAR CAM3 with relaxed Arakawa-Schubert convection).

2. How does remote forcing by intraseasonal Kelvin wave fronts initiate intraseasonal variability in the IAS region? We intend to examine how intraseasonal Kelvin waves propagating into the IAS region from the west initiate intraseasonal convective events. A moist linear baroclinic model (mLBM) will be used to demonstrate the impact that west Pacific heating variations have on producing intraseasonal Kelvin waves that propagate out of the west Pacific and into the IAS region. QuikSCAT winds will be also used to test whether associated surface frictional convergence and wind-induced surface flux variations can initiate IAS convection.

3. What local feedbacks regulate intraseasonal variability in the IAS region? Regardless of whether intraseasonal events in the IAS region are remotely or locally initiated, local feedbacks appear necessary to support such variability. Model sensitivity tests and observational tools will be used to examine the importance of ocean coupling, surface fluxes, and land-sea contrasts to intraseasonal variability. It will also be examined whether variations in tropical cyclones and synoptic-scale disturbances feedback onto the intraseasonal timescale through their impact on atmospheric moisture and energy budgets

4. What are the consequences of local or remote forcing for prediction of tropical cyclones? Given the potential lead times provided by forcing of intraseasonal Kelvin waves in the west Pacific, and the time it takes these waves to reach the IAS region, we will explore whether exploiting such lead times improves skill in forecasting periods of enhanced and suppressed tropical cyclone formation in the east Pacific, Caribbean Sea, and Gulf of Mexico. The primary environmental variables regulating such cyclone variability will be examined.

Credibility in the projected *tendencies* will be given by their proximity with those observed at the end of the 20th century. The assessment of *extremes* will be done at pentad, monthly and seasonal resolutions, but the assessment of *droughts* will be done at low-frequency scales of seasonal data via histogram analysis.

This proposal is being submitted jointly by Center for Ocean-Land-Atmosphere Studies and Rosentiel School of Marine and Atmospheric Science of University of Miami

Title: Atmosphere-Ocean Interactions and Summer Rainfall Variability and Predictability in the Intra-Americas Region

PI: Renguang Wu (Center for Ocean-Land-Atmosphere Studies)
Co-PI: Benjamin P. Kirtman (Rosentiel School of Marine and Atmospheric Science, University of Miami)

Abstract

This proposal will perform diagnostic and modeling studies to understand the roles of regional atmosphere-ocean interactions and remote forcing (ENSO and tropical Atlantic variability) in the interannual variability and predictability of summer rainfall in the Intra-Americas (IAS) region. The boreal summer IAS region is characterized by active convection and very warm water. This type of environment is similar to the Indo-western Pacific warm pool region in that the air-sea interactions are subtle and delicate, yet critical for climate variability. These air-sea interactions not only affect the local climate variability in the highly populated land areas in the IAS region, but also influence U.S. climate through modulating the moisture transport.

The objective of the proposed research is to understand atmosphere-ocean feedbacks and identify limitations and successes of current models in simulating the atmosphere-ocean relationship in the IAS region. This objective will be attained through diagnostics of observations and model outputs and numerical experiments. First, the atmosphere-ocean relationship in observations will be documented by examining the local relationship between rainfall or surface heat flux and SST or SST tendency. The evolution of atmospheric and SST anomalies associated with ENSO and tropical Atlantic variability will be examined in detail to understand processes for their delayed impacts on summer rainfall in the IAS region. Second, the above analysis will be performed for NCEP CFS simulations and CFS retrospective forecasts to evaluate the ability of the CFS in characterizing the atmosphere-ocean feedbacks in the IAS region and to identify deficiencies and plausible reasons. Third, numerical experiments with the CFS will be performed with SST forcing (climatology or total) specified in the Pacific Ocean or the Intra-American Seas to demonstrate the impacts of ENSO and regional atmosphere-ocean coupling on the climate in the IAS region. Fourth, the predictability for summer rainfall in the IAS region will be estimated based on the CFS retrospective forecasts. This estimation will be done for ENSO and non-ENSO years and for normal and abnormal tropical Atlantic SST years in order to identify the potential impacts of ENSO and the tropical Atlantic Ocean on the predictability. The proposed study is anticipated to advance understanding of atmosphere-ocean interactions, roles of regional and remote forcing in summer rainfall variability, and potential predictability of summer rainfall in the IAS region, and to reveal potential problems of the CFS in regional atmosphere-ocean relationship in the IAS region.

B. Abstract

Changes in Intraseasonal to Interannual Variability of the Pan American Monsoons Under a Warmer Climate and Their Impacts on Extreme Events Assessed by the CMIP5 Models and Observations

Institutions: The University of Texas at Austin, NCEP/NWS/NOAA, University of Colorado, Boulder
Principal investigator: Rong Fu, Co-Investigators: Kingtse Mo Weiqin Han

We propose to characterize the changes of intraseasonal, seasonal and interannual variability (ISI) and their impact on extreme events over the Pan America monsoon region as simulated and projected by the Coupled Model Inter-comparison Phase Five (CMIP5) and National Oceanic and Atmospheric Administration (NOAA) Climate Forecast System (CFS) models. Our analysis will first focus on observations of changes in rainfall and temperature characteristics and extreme weather events in the recent past and their underlying mechanisms. The observational results will be used to assess the skills of the CMIP5 class models in reproducing the observed ISI variability and their changes, in focusing on the mechanisms that control ISI variability in the Pan American monsoon regions and their links to sea surface temperature (SST) changes over the adjacent oceans, the local land surface process and the extratropical synoptic weather systems, as well as bias estimations. The results of this model evaluation will be used to filter-out "unrealistic" models from the climate projections and also for model bias corrections.

The proposal aims to address the following questions:

a) Will the spatial patterns, ISI variabilities and statistical distributions of temperature and rainfall shift significantly in a warming climate in the Pan American monsoon region? How would such changes impact the intensity and frequency of the droughts, floods and heat waves?

b) What external forcings are responsible for these changes and how would local land surface feedbacks contribute to these changes? What processes are key in determining the influence of these forcings? How are changes in the North American and the South American monsoon connected?

c) How realistically can global climate models simulate the key process that control changes of ISI in the Pan American monsoon region? How can such model evaluation be used to reduce random error and biases in climate projections?

We will extensively use observations and reanalysis products including in situ observations from surface and upper air meteorological networks, remote sensing datasets, the North American Regional Reanalysis (NARR), the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis (CDAS), the North-American Land Data Assimilation System (NLDAS) and the CFS reanalysis (CFSR) when it becomes available. We will also analyze daily and monthly outputs from ensemble simulations of the CMIP5 class models for the pre-industrial scenario, the 20th century simulations forced by estimated increase of the anthropogenic forcing, and the 21st century under

The American Midsummer Drought: Causal Mechanisms and Seasonal–to–Interannual Predictability | _Columbia University_ and _University of Maryland–College Park_ | Karnauskas, Giannini, Seager, and Busalacchi |

Abstract:

The Intra–Americas Sea (IAS) region– including the northeastern tropical Pacific Ocean, Caribbean Sea, Gulf of Mexico, western tropical Atlantic Ocean, and all adjacent landforms– represents a fascinating natural climate laboratory due to a confluence of diverse oceanic, orographic, atmospheric, and remote influences. The IAS region is also home to a large portion of humanity whose livelihood depends critically upon the spatiotemporal variability of precipitation. Throughout most of the IAS region, the rainy season spans roughly May through October with a break in precipitation in July–August known as the midsummer drought (MSD). This feature of the rainfall climatology is highly unique to the IAS region, and is particularly evident over Central America and the adjacent northeastern tropical Pacific Ocean. Indeed, the MSD is such a pervasive phenomenon that crop insurance programs incorporate what little information is known of the MSD in pricing and triggering policies in Central America. Since the recognition of the MSD as a regular climatological feature in the early 1960s, much effort has been directed toward characterizing and understanding the MSD. Both local processes (e.g., SST–convection–radiation feedback) and aspects of the general circulation (e.g., the North Atlantic subtropical high) have been shown to influence the MSD. To date, however, a unifying explanation for the very existence of the MSD has yet to emerge. As a result, our understanding of the interannual variability and– most importantly– predictability of the MSD is only in a nascent stage. Seasonal–to–interannual climate predictions for the IAS region would benefit greatly from an understanding of the causal mechanisms for the existence and variability of the MSD. We propose to first focus on analysis of observations: satellite and _in situ_ measurements, as well as state–of–the–art global and regional reanalyses to diagnose the dominant mechanisms of the MSD in the IAS region. Secondly, we will use state–of–the–art general circulation models to test specific hypotheses regarding the dominant mechanisms of the MSD and its variability. This approach will allow us to thoroughly examine and identify the features of the global atmospheric circulation and, especially, the role of the ocean, that are crucial for predicting seasonal hydroclimate variability in the IAS region.

An integrated view of the American Monsoon Systems:

observations, models and probabilistic forecasts

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Abstract

Climate Prediction Program for the Americas (CPPA) Science Plan indentified the need to "*explore a unified approach to understand the North American (NAMS) and South American (SAMS) monsoons systems, which constitute the two extremes of the annual cycle over the Americas and possible linkages between the two systems.*" This proposal will contribute to the CPPA implementation strategy by focusing on the interactions between the two systems and identification of common sources and limits of summer season predictability in the AMS. The main theme of this proposal is to develop a unified view of the AMS. Specifically, it addresses the FY2010 CPPA research priority of *Predictability and prediction of intraseasonal to interannual (ISI) climate variations and related impacts over the Americas*. The proposal will also evaluate the ability of global models from the World Climate Research Program (WCRP) Coupled Model Intercomparison Project (CMIP) to simulate the variability of the AMS in the present climate.

The project is comprised of four interconnected main goals. First, the project will investigate the extent to which the annual evolution of NAMS and SAMS and their temporal variability on ISI time scales can be represented with metrics that effectively describe changes in precipitation and atmospheric circulation in the Americas. Second, this will identify regional physical processes and teleconnections that control the interactions between NAMS and SAMS. Third, this project will evaluate the skill of WCRP CMIP coupled models in representing the observed variations in the AMS. Lastly, this project will implement diagnostic monitoring tools, identify sources of potential predictability and develop probabilistic forecasts of the AMS on subseasonal to seasonal scales. Specific objectives are:

I. Develop and validate indices for a unified approach to monitor and forecast the variability of the monsoon systems in the Americas.

II. Investigate the associations between the two monsoon systems, the importance of regional processes and remote atmosphere-ocean variations on ISI time scales in explaining these linkages.

III. Examine the degree to which simulations from the WCRP Coupled Model Intercomparison Project (CMIP-3 and CMIP-5) realistically represent the AMS and associations between the monsoons in the Americas.

IV. Use NCEP Climate Forecast System (CFS) model outputs (reforecasts and operational) to develop probabilistic forecasts of the American Monsoon Systems on subseasonal to seasonal lead times. Identify potential predictability sources of the AMS on ISI time scales.

Prediction, Validation, and Calibration of Coastal Storms and Associated High Impact Weather in Ensemble Regional Climate Simulations over the Northeast U.S.

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ABSTRACT

Increases in extreme weather events (heavy precipitation, strong winds, storm surge, etc…) under anthropogenic climate change would have profound consequences for both human society and the natural environment. The Northeast U.S. is particularly vulnerable, since there are frequent coastal storms in this populated region. The ability of atmosphere–ocean general circulation models (AOGCMs) to accurately simulate high impact weather and its trend is of great importance, but unfortunately these AOGCMs can not resolve many of the mesoscale features that cause damaging winds, heavy precipitation, and coastal flooding. A common approach has been to downscale these AOGCMs with regional climate models (RCMs) to better resolve these storms and the underlying surface characteristics; however, past RCM resolutions have been marginal (30-50-km) and few studies have explored the uncertainty of these predictions using ensembles. Furthermore, these raw ensembles are often biased or underdispersed, so more work is needed to calibrate them, especially for high impact weather events.

This project investigates the future changes (up to year 2070) of high impact weather over the Northeast U.S. using an ensemble of Weather Research and Forecasting (WRF) members at 20-km grid spacing nested within an ensemble of climate model simulations using the NCAR Community Climate System Model (CCSM). The first goal is to determine how well this joint ensemble system can predict previous extratropical cyclones and associated high impact weather over the western Atlantic and eastern U.S. during the cool seasons of 1981-2009. The CCSM and WRF members will use different physics perturbations and parameterizations to diversify a 15-member CCSM-WRF ensemble. An important science question is the role of sea surface temperature (SST) gradients in these predictions, so both high and coarse resolution SST will be used. Also, the upscale impact of diabatic heating from the storms will be explored using a new two-way nesting setup of CCSM-WRF being developed at Stony Brook University. The past predictions of cyclone strength, winds, precipitation will be bias corrected using observations and reanalyses and calibrated using an ensemble weighting scheme. The second goal of the project is to use the calibrated ensemble and future simulations to project changes in the statistics of high impact weather (cyclone tracks, heavy precipitation, storm surge, etc…) in the years 2040-2070. The future predictions will use a 14-member CCSM-WRF ensemble with two different emission scenarios and physics (WRF starting at 2040). A new approach to obtain high resolution SSTs in the future via downscaling the CCSM SSTs will be tested. The results will be compared with the NARCCAP ensemble results over the Northeast U.S.

Overall, this project is one of the first to apply high-resolution regional climate ensembles that are calibrated for future predictions of high impact weather. Thus, it will serve as a useful data source for decision makers interested in how heavy precipitation, storm surge, strong winds, and cold air outbreaks may change over the Northeast U.S. during the next several decades.

Observational constraints, diagnosis and physical pathways for precipitation and extreme event processes in next-generation global climate models
University of California, Los Angeles

J. David Neelin, Principal Investigator

Abstract

As climate models move to finer resolution, they can be evaluated against observations using new metrics. We propose to use and extend a set of measures developed from observations, on the scales that high-resolution global climate models are now reaching, to evaluate a targeted set of processes in current climate models. These will be evaluated for a set of models across a range of resolutions, including the higher resolution models from the Coupled Model Intercomparison Project 5 (CMIP 5), and various higher-resolution models from specific modeling groups. An example of a moderately high resolution model (Community Atmosphere Model at 0.5 degree resolution) is used to show that a model with parameterized convection can qualitatively capture several aspects of the categories below, but there is considerable sensitivity to ill-constrained factors such as entrainment.

The analysis will provide assessment of model suitability for evaluation of changes in these statistics under climate change and provide feedback for model development, drawing on tools developed under previous NOAA funding. Specifically, we focus on four categories of related features of precipitation, water vapor and temperature characteristics, on a set of statistics to quantify these, and on the underlying mechanisms producing these features.

1. Onset of deep convection, its water vapor-temperature dependence, and relation to entrainment assumptions. A set of convective onset statistics from remote sensing and in situ data provide a quantification of recent developments on the dependence of convection on water vapor in the lower free troposphere. There are several indications from other groups and from NOAA-supported prior work, of a strong sensitivity of climate models to errors in this process.

2. Excursions to high water vapor and strong precipitation regime. Prior work has provided evidence of long tails in the probability distribution (PDF) of water vapor, with a Gaussian core surrounded by approximately exponential tails, characteristic of an advection interacting with a forcing that maintains a gradient. Such tails imply much more frequent excursions into the high-water vapor regime associated with intense precipitation than would occur with Gaussian statistics.

3. Quantification of similar long-tail behavior for surface temperature PDFs, seen in preliminary work in many locations. The presence of such tails implies a rate of increase of extreme events under a shift of the distribution under global warming very different from that of a Gaussian.

4. Interactions at the margins of convective zones: the inflow air mass transported into a convective region is modified along its trajectory until conditions for convective onset are reached. If the onset condition evaluated in 1 is incorrect, the margins of the convection zones can have errors of hundreds of kilometers, creating large errors at the regional scale. Under global change, differences among model representations of this condition can yield large differences in the predicted regional change. Coordinated with a proposal from Rutgers University, diagnostics from internal variability will help constrain models in this category, and the role of these mechanisms will be evaluated for regional climate change in the models.

Project Title: Central U.S. abnormality in climate change and its response to global warming
Institution: Saint Louis University
Principle Investigator: Zaitao Pan (PI) and Timothy Eicher (Co-PI)

Abstract

The climate system is complex and involves many intertwined, interactive processes. Consequently, the direction and magnitude of climate change is a result of the various positive and negative feedbacks. On a regional scale, local climate change also reflects remote forcing and teleconnection patterns. Diagnosing individual climate change feedbacks will improve the understanding of climate dynamics and shed light on separating climate change into natural and anthropogenic components. This project proposes feedback processes and examines their contribution to abnormal climate change in the central and eastern U.S., which experienced a cooling trend is past decades.

The first process to be examined is baroclinicity, where the horizontal gradient in surface warming increases thermal wind and baroclinic instability, which then further interacts with climate change. The second process is soil moisture feedback. Climate change causes soil moisture to change, which alters the soil heat capacity and thus causes a feedback on near-surface temperature changes. The last process is the planetary boundary-layer (PBL) depth/low-level jet (LLJ) feedbacks. A stronger surface warming and thus a higher PBL height upstream produce a stronger nocturnal LLJ and moisture transport downstream, generating an increase in cloudiness leading to a subsequent cooling.

Given the processes outlined above, the objectives of our proposal are: 1) to determine to what extent the above regional feedbacks contribute to the unusual summer cooling in the central and eastern U.S.; 2) to assess if these feedbacks can help explain why most IPCC AR4 GCMs were unable to reproduce the cooling trends in their 20th century historic simulations; 3) to project if this cooling trend will continue in coming decades; and 4) examine if these feedback processes also contribute to similar local cooling documented over other continents. Address these issues will help determine whether the abnormal central and eastern U.S. climate change is a regional response to (i.e., a result of) global warming, suggesting that the cooling trend would continue in lock-step with global warming, or it is related to some other transient processes, meaning that the central and eastern U.S. would be much warmer if these processes disappear in the future.

To achieve our objectives, a series of numerical experiments will be carried out using the global NCAR Weather Research and Forecast (WRF) model and Climate WRF (CWRF) with enhanced land surface and boundary layer schemes. Statistical tools including canonical correlation analysis (CCA), principle component analysis (PCA), and factor separation will also be used to diagnose the associations between these feedbacks and anomalous mid-continent cooling.

In-depth Regional Process-level Analyses of NARCCAP and AR5 simulations over North America: Towards Establishing Differential Credibility of Regional Climate Projections

Anji Seth, Principal Investigator, University of Connecticut
Linda O. Mearns, Principal Investigator, NCAR
Melissa Bukovsky and David Gochis, Co-Investigators, NCAR

Abstract
The proposed research will take an alternative approach to differential evaluation of model credibility by focusing on process-level evaluation rather than on simple metrics. We hypothesize that a consistent set of process-oriented model analyses can be developed and applied in different climate regimes, and that this suite of model analyses will help define credible model members whose future simulated climates will have value for regional climate change assessment. We are focusing on three regions in North America (Southwest, Great Plains, Northeast) with the following objectives: (1) Establish a framework for determining the differential credibility of climate simulations using a process-based methodology for three specified regions; (2) Develop process-level time-series analysis to follow identified mechanistic errors in the evolution (from current period into the future) of warm season precipitation in the regions; (3) Based on the process-level analysis, differentiate the credibility of the models using collective expert evaluation (CEE); (4) Translate the process-level information into quantitative metrics; (5) Compare these metrics with the baseline metrics of ENSEMBLES; (6) Compare credibility rankings based on our process-level collective expert evaluation and developed metrics with rankings based on the ENSEMBLES metrics and diagnose causes of differences. (7) Apply the developed framework to Coupled Model Intercomparison Project (CMIP5) high-resolution decadal predictions.
This research will employ simulation data sets produced through the North American Regional Climate Change Program (NARCCAP) and the global coupled model (50 km) decadal predictions in progress as part of CMIP5 for the present day and near future periods. The process-level investigations will first be conducted for the coupled global models (AOGCMs), atmospheric global models (time-slices), and the regional climate models (RCMs) involved in NARCCAP. Time series of process-level errors will be examined in the reanalysis-driven and AOGCM-driven present day simulations and followed into the future simulations. The importance of the errors as the models respond to the new forcing in the future will be evaluated. In this way, our analysis will focus on the effect of the more consequential errors on the model future response. Our purpose is to perform qualitative process-level collective expert evaluations for each region, which may then be transformed into quantitative indicators.
The ultimate goal of this analysis is to provide meaningful differential weighting of the models using a process-level approach that results in more robust estimates of future climate change. The process-level analyses have value in that, by enhancing our understanding of the evolution of processes under greenhouse gas forcing, uncertainties may be reduced in the sense that better understanding of important mechanisms at work will result. The proposed research directly addresses MAPP FY2011 Priority 1b: 'to evaluate uncertainties in the longterm prediction and projection of twenty-first century climate over North America leveraging NARCCAP and new CMIP5 projections'.
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2. ABSTRACT

Title: Quantification and reduction of uncertainties in projections of climate impacts on drought and agriculture for North America
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Introduction to the Problem: Agricultural productivity is highly dependent on climate variability and is thus susceptible to future changes including temperature extremes and drought. The latter is expected to increase in frequency regionally over this century. However, the uncertainty in projections of drought and its impacts on agriculture is high due to emission scenarios, climate model differences, uncertainty in initial/boundary conditions, and translation to regional scales. Climate models are unanimous in projecting future warming but differ in the magnitude and even sign of regional precipitation changes. They also differ in terms of extremes of temperature, precipitation and other meteorology. When projecting future impacts on crop productivity, these uncertainties are compounded because current crop models often use simplified treatments of climate response and do not include comprehensive treatments of water availability. Therefore, projections of regional climate change, variability and its impacts on water availability and agriculture are highly uncertain and reduction of uncertainties requires attention to all levels in the climate-water-agriculture continuum.

Rationale: Given the uncertainties in future agricultural production and the complex relationships between climate, hydrology and crop development, there is pressing need to make improved estimates of future changes in climate change and crop yields. ***We propose to evaluate the uncertainties in estimates of future changes in climate, water availability and agricultural production, and make improved estimates by incorporating state of the art knowledge of the relationships between climate, hydrology and agriculture into modeling and downscaling.*** This has ramifications for disaster preparedness and mitigation, policy making and the political response to climate change, and intersects with fundamental science questions about climate change, extremes and hydrologic cycle intensification. It is central to the mission of the Climate Program Office's MAPP program to "enhance the Nation's capability to predict variability and changes of the Earth's System" and directly addresses its priorities to evaluate and reduce uncertainties in climate projections. This work will leverage from the PIs' experience and ongoing activities in large-scale climate analysis and hydrologic modeling, particularly in changes in drought historically and under future climates, and agricultural modeling and relationships between climate and crop productivity.

Summary of work to be completed: 1. Quantify the relationships between hydroclimate variables and the implications for water, drought and agriculture based on observational data. 2. Evaluate sensitivities of hydrologic and crop models to changes in climate and drought. Differences in climate variability, land-atmosphere coupling and hydrologic persistence will lead to differences in key metrics of water and agriculture which will form the basis for evaluation of the uncertainties in future projections. 3. Evaluate current climate models in how they replicate these observed relationships using the CMIP5 long-term and decadal predictions. 4. Estimate uncertainties in future projections of climate, drought and agriculture using a cascade of climate, downscaling, hydrologic and crop models with strategic sampling to decompose sources of uncertainty. 5. Implement a set of methods to reduce uncertainties in future projections based on observational constraints including merging of climate model predictions, bias correction and scaling of climate model output, and improvements to impact models.

Understanding the Emerging Central-Pacific ENSO and Its Impacts on North American Climate

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ABSTRACT

It is being increasingly recognized that there are two distinct types of El Niño-Southern Oscillation (ENSO): an Eastern-Pacific (EP) type that has its sea surface temperature (SST) anomalies centered near the South America coast and a Central-Pacific (CP) type that has its SST anomalies centered near the international dateline. IPCC AR4 simulations project that the CP type may become the prevailing type of ENSO in a future warmer world, which is consistent with the fact that CP ENSO events have occurred more frequently in the past three decades than in earlier decades. There is a need to better prepare for the emergence of this mode of tropical climate variability, and to revise existing modeling and prediction strategies developed primarily with the conventional EP type of ENSO in mind. One source of uncertainty in the prediction and projection of North American climate may have to do with whether or not modern climate models can produce both types of ENSO, simulate the alternation between them, and capture their different impacts. This project proposes data analyses and model experiments to better understand the evolution of the CP ENSO and its regional impacts on the Pacific-North America sector and to identify the key atmospheric and oceanic processes for differing the impacts of the CP and EP ENSO's on North American climate.

Specifically, this project will make use of the existing Coupled Model Intercomparison Project Phase 3 (CMIP3) simulations and the upcoming CMIP5 simulations to understand the relative importance of the extratropical forcing and tropical coupling in controlling the evolution of the CP ENSO and to identify the concurrent and extended impacts of CP and EP ENSOs on North American Climate. The different impacts produced by the EP and CP ENSOs will be translated into uncertainties in the prediction and projection of the North American climate variability and will be assessed. Partial-coupling and forced experiments will then be conducted to further understand how the ocean and atmosphere in the Pacific-North American sector respond to CP and EP ENSO forcing, how the responses are projected onto the Pacific-North American (PNA) and North Pacific Oscillation (NPO) modes of variability, and how they are manifested as variations in the Aleutian Low, Subtropical High, and tropospheric jestreams. Special attention will be given to understanding the ENSO-induced SST anomalies in the North Pacific, which are hypothesized to extend ENSO's influence on North America after the demise of the ENSO events. The possibility of using statistical models, such as the Markov model, to perform CP ENSO predictions using both extratropical and tropical information will also be explored.

This project is expected to quantify the sensitivity of North American climate to the alternation of the ENSO type and to make suggestions on how it can be better captured in modern climate models by laying out the specific atmospheric, oceanic, and coupled processes that establish the sensitivity. New metrics that gauge not only tropical but also extratropical atmospheric and ocean fields will also be developed to help further improve model simulations of the two types of ENSO. These efforts are relevant to (a) "support the development of next-generation global climate models" and (b) "evaluate uncertainties in regional-scale climate predictions and projections", both of which are priority areas specified by the FY2011 MAPP program for the research theme of *Advance in Regional-Scale Climate Predictions and Projections*.

Nonlinearity of the Tropical Convection and the Asymmetry of the El Niño Southern Oscillation

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Abstract

The asymmetry of ENSO is a measure of its nonlinearity, and may be a key ingredient in climate variability on the decadal and longer time-scales, particularly for the Pacific sector. Understanding its causes and ensuring accurate simulation of it by climate models is a key issue facing climate modelers who strive to make reliable forecast/projections of climate changes over the coming decades.

The proposed research attempts to address this issue by analyzing existing model runs as well as through conducting specially designed experiments. Our working hypothesis— is that the nonlinearity in deep convection is an important cause of the asymmetry in ENSO. Specifically, an increase of the nonlinearity of tropical convection will lead to an increase in the asymmetry of zonal wind stress and therefore an increase in the asymmetry of subsurface signal, favoring an increase of ENSO asymmetry.

We plan to analyze the coupled runs as well as the corresponding AMIP runs from the latest NCAR and GFDL models, including the diagnosis of the NCAR model runs with different convection schemes and with different model resolutions and the GFDL model runs with different convection schemes. We not only examine ENSO asymmetry in the surface fields such as SST, surface heat flux, and precipitation but also its subsurface manifestation. To understand how the changed wind stress associated with changed convection scheme will affect the subsurface asymmetry and thereby the SST asymmetry, we will perform forced experiments with the NCAR Pacific basin model, the POP global ocean models (the ocean component of CCSM4/CESM1) and the MOM4 (the ocean component of the GFDL coupled model) using the winds from the AMIP runs of NCAR and GFDL models. We will compare the results from the forced runs driven by observed winds. In addition, the forced runs will be perturbed by warm anomaly, cold anomaly, and the residual of wind stress from observations and model simulations. Experiments especially designed to understand the relative importance of the nonlinearity from the atmosphere and the nonlinearity from the ocean dynamics will also be conducted.

To further validate the effect of changes in convection schemes and model resolutions on the simulation of ENSO asymmetry we will find from NCAR and GFDL models, we also plan to examine the coupled runs as well as the corresponding AMIP runs from the ongoing IPCC AR5 data sets.

The purpose of proposed research is to provide a better understanding of how the simulation of ENSO—the asymmetry between its two phases in particular—in global climate models is affected by increases in model resolution and changes in convection scheme, in support of the development of next-generation climate models involving both higher resolution and improved physical representations.